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MILK SUBSTITUTES OF VEGE-
TABLE ORIGIN

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MILK SUBSTITUTES OF VEGETABLE ORIGIN

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The Report was approved by the Nutrition Advisory Committee at its meeting held in Mysore on the 1st and 2nd August, 1955.

MILK SUBSTITUTES OF VEGETABLE ORIGIN

Importance of milk in human dietary

The importance of milk as an article of human food has been recognised from the earliest times. With the advance of scientific knowledge, the value of milk as source of a high class protein, an excellent fat, fair amounts of different vitamins, as also various essential minerals, especially calcium, has been increasingly realised. Milk makes an excellent supplement to the dietary of the people at all ages. Milk requirements in infancy and early childhood can be placed at about 32 oz. Although one cannot speak of adult requirements on the same basis, it cannot be denied that a good diet should contain 10 oz. or more of milk per day.

Certain regions of the world are ideally suited for the rearing of milch cattle and the people in those areas who naturally consume adequate amounts of milk and milk products are among the healthiest in the world. There are other regions, however, where milch animals do not develop properly or where the density of population is such that there is competition between men and animals for the available food. In such areas, there is not enough milk to go round and the health of the people will naturally suffer.

PRODUCTION OF MILK IN INDIA :

In a vast country like India, there are regions where the conditions are quite favourable for cattle rearing and where there is fair abundance of milk. Such areas are, unfortunately, rather restricted. There are other regions, which are quite vast in area and where milk production is quite inadequate. The total cattle population of India is said to be well over 200 millions—about a fourth of that of the whole world—but, of this, only a certain proportion is yielding any milk. The average milk yield from these animals is also comparatively small. According to the available statistics, the present production of milk would correspond to 5·45 oz. per capita (215), which is about a third of the requirement for the maintenance of good health. Even out of this, the distribution is by no means uniform. Some sections of people get all the milk that they require, while others get almost nothing. The main milk producing regions are in the West—Central and North Western regions, whereas, in other parts of the country, the production is highly restricted. The production in the Southern and Eastern regions would correspond to hardly four ounces per capita. There are some areas like those of the Western Ghat tracts, and especially the Canaras, Coorg, Malabar, Travancore-Cochin, as also Assam, which are very poor in regard to milk supply. It is estimated that in Travancore-Cochin, the milk production is equivalent to hardly 2 oz. per capita. In such regions, milch animals do not flourish at all and even high yielding breeds deteriorate in a very short time. As some of these areas are also densely peopled, the shortage of milk is acutely felt. Even in other areas, the milk, as now distributed, is largely an adulterated product containing hardly half the usual quantity of milk solids.

ATTEMPTS BEING MADE FOR INCREASING MILK PRODUCTION :

During recent years, there has been a good deal of interest in the possibilities of increasing milk production in the country. The Central Government, as also the Provinces and States, are taking energetic steps to ensure better management, introduction of superior breeds, extension of artificial insemination and control of disease. States like Bombay, Madras and Delhi have taken steps to provide additional grazing facilities, and have organised large scale collection and scientific processing and distribution of milk. The work already done in Bombay is now considered to be a model for the rest of India and the other Eastern countries. In different states active steps are being taken to ensure better feeding of animals but this aspect offers a considerable amount of difficulty. As observed by Dr. H. D. Kay (215) in his "Report on Dairy Research, Dairy Education and Dairy Development in India" the greatest obstacle in the way of increased milk production is the shortage of feeding-stuffs, the shortage of concentrated protein food being particularly severe. It would appear that the animal feed would be the main limiting factor in regard to increased milk production in the country. The recommendations made by the Nutrition Advisory Committee of the Indian Council of Medical Research and the Animal Nutrition Committee of the Indian Council of Agricultural Research in a joint memorandum regarding the practicable ways and means of improving milk production should be very helpful in the implementation of a programme on a nation-wide basis.

SCIENTIFIC BLENDING OF MILK COMPONENTS :

While recognising the unique features about the composition of milk, it should, at the same time, be realised that practically all the constituents of milk are derived from the feed of the animal. The components of milk, when broken up into their individual constituents are found to be such as could be built up from other sources as well. Thus, the milk proteins are made up of amino acids which could also be obtained by suitably blending different vegetable proteins. The vitamins which are present in milk can also be obtained from other sources. The minerals and fats can also be similarly made up. A unique feature about the animal milk is the sugar, lactose, but, as far as known, there is no nutritional significance that can be attached to this sugar. For practical purposes, lactose can be replaced by any other sugar or other easily assimilable carbohydrate. There is thus a theoretical possibility that, by scientific blending and processing, it may be possible to reproduce the proximate composition and nutritive value of milk. The desired perfection has not, however, been attained so far, but the scientific possibilities can be envisaged. Apart from the nutritive value, there is the flavour of milk which is partly determined by the nature of the milch animal, and partly by certain other substances, the nature of which has not yet been fully established. The liking for the flavour of milk may be an acquired one, but it is nevertheless very important. There are commercial milk flavours, but they could not fully reproduce the flavour of the natural product.

ORIGIN OF MILK SUBSTITUTES :

In many parts of the World, there is abundant supply of milk, and consequently, there is no need for any supplement or substitute to

augment the available quantity. The effect of shortage was, however, first felt in China, which is today the most densely peopled country in the world. Centuries ago, Wahi Nain Tzelang discovered the potentiality of the soya-bean, which is a rich source of protein, together with a fair percentage of oil and other accessories. It was found that, even by simple grinding and pasting, soya-bean can be made to yield an emulsion which, for many purposes, can be used in the same way as animal milk. With the passage of time, several improvements in the processing were made and the product became steadily popular in China. At the present time, a large section of Chinese people use exclusively soya products and do not use animal milk in any form. The demand for soya-milk and products has so much increased in China that, apart from what is produced in the homes, practically every city has small plants that manufacture and distribute the product in the same way as dairy milk in other parts of the World. (181)

The use of soya-milk extended from China to Japan and other Far Eastern and South-East Asian countries. Visitors from Europe and America were greatly impressed with the various uses that were being made of soya-bean, which was looked upon as a wonder bean. The cultivation of soya-bean spread very rapidly in the United States of America where it now forms the foremost source of oil and protein concentrate for animal feed. In that country there is no shortage of cow's milk and only a small amount of the bean is being converted into a vegetable milk that is largely consumed by people who are allergic to cow's milk. Canada is also producing small quantities of soya-milk chiefly for feeding children who have digestive troubles. Early in the twenties, Donnan and Bhatnagar (14) processed soya-bean to yield a product which was subsequently marketed in the United Kingdom under the name "Soylac". This type of product is still being produced, though on a relatively small scale, in the U.K. The cultivation of soya-bean and the production of milk is reported to have spread rapidly in some of the states of the Soviet Union, but factual data are not available.

During the Bengal Famine of 1943, Guha and Saha prepared a mixture of soya-bean, groundnut and malted barely from which a milk was prepared, which fortified with calcium and shark liver oil, was fed to a large number of infants and children who liked this feed and responded well to it. Experiments with rats showed that this milk gave better growth than ordinary bazaar milk but slightly less than genuine cow's milk.

During recent years, shortage of milk is being felt in several South East Asian countries, especially in parts of Burma, in Malaya, Ceylon and Indonesia. The use of soya-milk in that region is steadily increasing chiefly because of the influence of the Chinese and the Japanese residing in many of the areas. More recently, the F. A. O. and the UNICEF have jointly initiated a programme in Indonesia for the large-scale production of a properly fortified soya-milk chiefly for use in feeding infants and growing children. This project is largely based on a process developed under the auspices of the Food Ministry and the Indian Council of Medical Research in India.

Apart from soya-bean, there are several other oil-bearing seeds which could be processed to yield products which could be used for a variety of purposes in the same way as animal milk. By themselves, none

of these oil-seeds can be considered to be adequate substitutes for animal milk. By suitable processing and supplementation with minerals and vitamins, the nutritive values of the emulsions from these seeds can be steadily improved. The stability of the preparations can also be increased to such an extent that they can be boiled, fermented and otherwise handled in the same way as cow or buffalo milk. In this manner, they could be made to augment the available supplies of milks in regions where there is limited supply. In the development of this field, India is in an uniquely favourable position, because when all the different categories of oil seeds are taken into account, this country will rank as the foremost in the world. If even a small portion of the available supply of oil seeds is utilised for such processing, the country can greatly augment its limited supply of milk with properly fortified milk substitutes. A great deal of prejudice has, of course, to be overcome and the necessary measures taken to see that the production of different animal milks is not interfered with. The object of the present review is to discuss the scientific work done on such substitutes in different parts of the world, especially in India and to indicate their practical possibilities.

Among the oil-bearing materials, groundnut, soya-bean, cocoanut, cashewnut and almond, have been used particularly by investigators in India. The compositions of the starting materials, as compared with those of dried whole milk and skimmed milk, are shown in the following table :—

TABLE I.

Composition of some oilseeds compared with dried, whole and skimmed milk powders.

Values * per 100 g. of the material.

Constituents	Unit	Dried whole milk powder	Dried skimmed milk powder	Almond	Cashewnut	Cocoanut Mature	Cocoanut Tender	Groundnut	Soya-bean
Moisture	g.	‡‡ 3.5	4.1	5.2	5.9	36.3	90.8	7.9	8.1
Protein	g.	25.8	38.0	20.8	21.2	4.5	0.9	26.7	43.2
Fat	g.	26.7	0.1	58.9	46.9	41.6	1.4	40 1	19.5
Mineral matter	g.	—	6.8	2.9	2.4	1.0	0.6	1.9	4.6
Fibre	g.	—	—	1.7	1.3	3 6	—	3.1	3 7
Carbohydrate	g.	38.0	51.0	10.5	22.3	13.0	6.3	20.3	20 9
Calcium	g.	0.949	1.37	0.23	0.05	0.01	0.01	0.05	0.24
Phosphorus	g.	0.728	1.00	0.49	0.45	0.24	0.03	0.39	0 69
Iron	mg.	0.58	1.4	3.5	5.0	1.7	0 9	1.6	11.5
Carotene (I Vitamin A Units)	I.U.	1400	0	Trace	100	Trace	—	63	710
Thiamine	μg.	300	57	240	63	45	—	900	900
Nicotinic acid	mg.	7	1.1	2 5	2.1	0.8	—	14.1	2.4
Riboflavin	μg.	1460	—	—	190	100	—	300	—
Vitamin C	mg.	1	—	0	0	1	2	0	—

* Values taken from Health Bulletin (9)

‡‡ Values taken from Hunziker's Condensed milk and milk products.

Soya-bean Research in India

During the past three decades, several attempts were made in India to popularise the use of soya-bean as an article of human food. The high protein content (about 40%—which is about double that of the commoner indigenous pulses—the association of a valuable oil (20%), B Vitamins, and minerals made the composition appear full of possibilities. The animal experiments, as also experiments with school children, as first carried out at Coonoor by Aykroyd and Krishnan (7), showed that the pulse did not have any advantage over the commoner pulses as already consumed in the country. Subsequently a more intensive programme was carried out in four Laboratories (Dacca, Bombay, Lahore and Coonoor) in accordance with a plan drawn up by the Soya-bean Sub-Committee of the Nutrition Advisory Committee. The report of that Sub-Committee (1946), generally confirmed the earlier Coonoor results and showed that, in spite of its higher protein content, soya-bean did not reveal any superiority over the commoner Indian pulses as a supplement to the typical Indian diets. The Sub-Committee stated, therefore, that it was "not in a position to advocate *immediately* the encouragement of the production of soya-bean on a wide scale in India for use as a substitute for Indian pulses. The question should, however, be reconsidered if and when further evidence on the nutritive value of soya-bean becomes available".

When preparing the above report, the Sub-Committee had before them the results of the Dacca experiments which showed that while the bean itself, cooked as a pulse, had no supplementary value to the simplified rice diet, the milk prepared out of the bean had a definite supplementary value which was only slightly inferior to that of cow's milk. There was also a detailed report from the Indian Institute of Science, Bangalore, which indicated that the digestibility and the biological value of the fraction of soya-bean protein which was in stable emulsion as a result of processing were considerably higher than the corresponding values for the whole soya-bean protein. The latter report also outlined an improved method of preparing a stable and adequately fortified soya-milk which had already been used for trials in Bangalore.

As the above observations were rather suggestive, a fresh programme of investigations was initiated at Bangalore under the auspices of (*i*) the then Indian Research Fund Association (now Indian Council of Medical Research), for assessing the nutritive value of processed soya-bean milk as compared with cow's milk at different levels in the case of both experimental animals and human subjects, (*ii*) the then Food Department, (now Ministry of Food & Agriculture) for pilot plant trials on the production of soya-milk and related products, and (*iii*) the then civil and Military Station, Bangalore, for mid-day school feeding of about 6,000 school children with rice and soya milk curd as compared with rice and skimmed milk curd. In these programmes the Indian Institute of Science conducted the preparatory studies and the animal experiments, while the Nutrition Research Laboratories collaborated in the field studies and made the necessary health observations. The trials which were conducted over a period of three years (1945-48) showed that, unlike the whole soya-bean, the milk or curd prepared out of it was acceptable, had a high digestibility and a definite supplementary value to the poor cereal diet as consumed in South India.

Vegetable Milk from Groundnut

One of the major reasons for the non-extension of soya-bean cultivation in India is the established interest in the cultivation of other oil seeds, especially groundnut, of which India is the chief producer among countries for which statistics are available. This oilseed is a cash crop and, being also a legume of short duration, its cultivation has been widely extended and the annual production now stands at about 4 million tons. It was considered desirable, therefore, to explore the possibilty of processing groundnut for the production of vegetable milk. Work in this field was first started at Bangalore and then continued at the Central Food Technological Research Institute, Mysore. The processing of groundnut offered considerable amount of initial difficulty because of the odour of the product and the general instability of the milk. Those difficulties were steadily overcome and the yield was raised from about 5 lbs. to about 8 lbs. per lb. of kernel. It was found, however, that in spite of deodourizing, the milk was not so popular as the lactic fermented curd and the butter milk prepared out of it. As there was a great demand for such products especially on the West coast, the Council of Scientific and Industrial Research (India) encouraged the setting up of the first commercial plant at Trichur in Travancore-Cochin. Proposals are under consideration for setting up more plants in different other parts of the Country.

In the case of soya-bean milk, the main objection from consumers has been on the score that it has a nutty flavour which is different from the characteristic flavour of cow or buffalo milk. Even, after deodourising there is some objection to groundnut milk. These products can easily take the place of milk in preparations in which milk forms one of the ingredients and where other flavours dominate. They cannot, however, be used for coffee and, especially, tea, which has a delicate flavour. On the other hand, if these preparations are subjected to lactic fermentation, the flavour becomes practically identical with that of the cow or buffalo milk product. The fermentation modifies the flavour in the same way in the case of animal or vegetable milks, so that the different products become indistinguishable when made into the respective curds.

Vegetable milk can be prepared out of practically every oilseed, though the yield and the quality will depend on the nature of the material. Cocoanut, cashewnut and almond are already being used as milk in various food preparations. Scientific processing was done at Bangalore and Mysore and the preparations can be stabilized and fortified. Cocoanut milk has to be supplemented with protein so as to render it comparable with other milks.

Cashewnut milk has definite possibilities if the cheap broken kernels —which are not easily marketable—are used. Almond milk has limited use because of its high cost. All these and other popular oilseeds and nuts can be converted into milk in regions where they are cheaply and plentifully available.

Another profitable line of approach is that of blending some of the oilseeds to obtain a composite milk. This will under certain conditions be more economical and efficient than that of using a single material. The proteins of the seeds supplement each other—for example, groundnut and soya-bean (211a), the flavour is modified and the product has increased stability. Another line of approach is to combine an oil bearing

material with a malted cereal so as to improve the flavour and taste. A great deal of work has also been done on the concentration and desiccation of different types of single as well as blended milks.

Preparation of Milk Substitutes

A number of patents for the preparation of milk substitutes have been taken out in Britain, Russia, France, Japan and the United States. For most preparations of vegetable milks, soya-beans are either crushed after soaking or powdered beans or kernels used as such and the suspension of the crushed beans filtered to obtain the milk. Several processes which have been developed as improvements over the usual method aimed at expelling the beany flavour, removal of bitter principle, modifying the flavour by incorporating certain flavours or treating the milk with enzymes or bacterial cultures to impart a more acceptable flavour. The salient features about some of the well-known processes are outlined below.

MILK SUBSTITUTES FROM SOYA-BEANS :

In most of these preparations, soya-bean is soaked, mashed and the mash extracted with water or weak alkali and then filtered. Suitable supplements are incorporated to increase the over-all nutritive value of the milk. Gössel (70-76), Burdick and Nielsen (21) Thevenot (194-195), Blunk (15) Chang and Tso (25) Guy and Yeh (81) and Voskresenskii and Dobruinina (207) have described such preparations.

Some of the milk substitutes have been prepared from soya-bean powder which is converted into a dissolved form by extracting it with alkalies. Moses (145-146) Rigler (170) Melhuish (118-123) Bonotto (17) Reid (166) Ouchi and Takeda (159) Hill and Stuart (86) have used soya-bean powder as the starting material for the preparation of milk substitutes.

IMPROVING THE FLAVOUR OF SOYA-BEAN MILK :

Thevenot (194-195) suggested that the mashed beans should be digested with proteolytic enzymes or the beans be treated with alcohol to remove some of the undesirable principles from it. Blunk (15) imparted natural milk aroma by the use of enzymes. Melhuish (118) improved the flavour of milk by incorporating milk ripening bacteria or by using butyric acid as flavouring material. Monahan and Pope (132-133) improved the flavour of milk by using malt, chocolate or cocoa. Erslev (60) prepared milk beverages by treating vegetable substances with benzene to extract fat and then treating with alcohol. The extracted material is treated with a weak alkali solution to dissolve proteins and the extract emulsified with fat.

REMOVAL OF BITTER PRINCIPLE AND BEANY FLAVOUR :

Berczeller and Graham (13) recommended that soya-bean should be treated with nitrites or formaldehyde during extraction with alkali to destroy the amines which are mainly responsible for the flavour. Yamamoto *et al* (210) removed the characteristic odour by immersing the beans in vinegar or acetic acid of desired strength. Horovitz-Vlasova *et al* (89) recommended that the beans should be treated with steam at 100°C for deodorization. Oberhard (156) suggested that deodorization is accomplished by treating the ground beans with saturated steam for half an hour and then drying

at 60-65°C or allowing them to stand 24 hours moistened with 0.5% formaldehyde and drying at 60-65°. Sadikov *et al* (176) removed undesirable flavour of soya-milk by shaking it with refined fat which is not taken up by the milk but which absorbs undesirable flavours from it and can then be skimmed off. Adler (1) processed soya-bean milk by extracting with alcohol and then treating with a fast current of air to remove further impurities. The extraction may be preceded by roasting to remove the bitter taste. Bogatskii *et al* (16) have given detailed directions for commercial preparation and deodorization of soya-bean milk. Chin (31) removed the bitter principle of soya-bean milk by boiling the emulsion for several minutes.

PREPARATION OF SOYA-BEAN MILK—BANGALORE METHOD :

The soya milk as prepared by Chinese method is not very palatable and is slightly coloured. The milk obtained by most of these methods is fairly low in total solids. De and Subrahmanyan (39) and Desikachar *et al* (47) effected a number of improvements in the method of preparing the milk. The resulting product had an agreeable taste and possessed a high nutritive value. The method followed by them may be described as follows :

The soya-beans are soaked overnight in water. They are then germinated and the skin is then peeled by gentle rubbing. The beans are then extracted with 0.04% sodium bicarbonate at 70°C for half an hour to remove the bitter principle and colouring matter. The beans are then made into a fine paste, stirred up with about 6 volumes of water and boiled for 20-30 minutes. The mixture is allowed to settle and then filtered through cloth. One pound of soya-bean gave about 5.5 lbs. of milk.

EFFECT OF HEAT ON SOYA-BEAN MILK PROTEIN : DESTRUCTION OF TRYPSIN INHIBITOR :

In most of the above processes mentioned, the method of preparing soya-bean milk is not fully specified. In the absence of this information, it is difficult to get a proper idea about the nutritive value of the different preparations. In many of the preparations, soya-bean powder from meal subjected to drastic heat treatment and solvents during oil extraction has been used. Osborne and Mendel (158) were the first to report the beneficial effect of heat treatment on soya-bean protein. This has been confirmed by a number of workers including Hayward *et al* (85), and Johnson *et al* (94) who have exhaustively studied this aspect. Hayward (84) also studied the effect of different solvents and found that neither alcohol, carbon tetrachloride, hexane, ether nor benzene extraction appreciably affected the nutritive value of soya-bean protein that was not given any heat treatment.

The type of heat treatment which is necessary for the development of optimum nutritive value has been studied by Hayward *et al* (85), and Parsons *et al* (160, 161). According to Barnes and Maac (10), protein of good quality is obtained when soya-bean is subjected to autoclaving or boiling for 15 minutes, or if given dry heat treatment during expeller crushing at temperatures from 105°C to 150° for 15 minutes.

It has been shown by Ham and Sandstedt (83), Bowman (19), Borchers *et al* (18) and many other investigators that raw soya-bean contains a

proteolytic inhabiting substance which impairs the utilization of its protein and that it is destroyed on autoclaving. Kamala Sohonie and her associates (65) and also De and Desikachar (46) have also done valuable work on the subject. Vishwanath (205) has done work on the mechanism of the action of the anti-trypsin factor. Julian (95) and Desikachar (53) reported that the increase of nutritive value of soya-bean protein on wet heating may also be due to structural alterations in the protein.

COMPOSITION OF SOYA-BEAN MILK :

Soya-bean milk as processed by De and Subrahmanyan (39) and Désikachar *et al* (47) had the following average composition.

TABLE II

Comparative composition of cow and soya-bean milk.

Nutrient	Soya-bean milk %	Cow's milk (216) %
Total solids	10.15	13.44
Protein	4.2	3.2
Fat*	3.4	4.9
Carbohydrate	1.8	4.6
Salts	0.75	0.74

* Horvath (91) suggested a modified Babcock test for estimating fat in soya-milk as the fat in milk is not set free by H_2SO_4.

TABLE III

Vitamin content per litre of soya-bean milk and cow's milk.

Vitamin	Unit	Soya-milk	Cow milk
Vitamin A	I.U.	750 (as pro-vitamins)	10,320
Thiamine	mg.	0.82	0.45
Riboflavin	mg.	1.10	1.7
Nicotinic acid	mg.	2.49	1.26
Ascorbic acid	mg.	21.6	15.9

The total solid content of soya-bean milk as prepared by the above method is less than that of cow's milk. Desikachar *et al* (212) prepared soya milk with solid content approaching that of cow's milk from finely powdered, decorticated beans.

PREPARATION OF SOYA-MILK BY POWDER METHOD (212) :

With a view to increasing the solid content of soya-milk the preparation of milk was modified in 1948 and the following procedure was tried at the suggestion of Shri Satish Chandra Das Gupta.

The starting material for preparing milk by this method is finely powdered soya-bean flour prepared from the decorticated beans. The fine flour is mixed with 5 to 6 times its own weight of water containing 0.1% each of sodium bicarbonate, sodium citrate, sodium chloride and disodium hydrogen phosphate. The mixture is shaken well and kept over night. The natural enzymes of the soya-bean, the salts added to the extracting water and the long time of extraction help in bringing more solids into solution. The suspension is filtered next morning, the residue is repasted, suspended in the original liquid and filtered through cloth. The emulsion is first boiled for fifteen minutes and then steamed for 15 more minutes to remove the beany flavour as much as possible. The solid content of this milk approaches that of cow's milk (12.5%). The milk obtained by this method is rather dull in colour and still retains some of the original bitter taste. This can however be masked by addition of some sugar. This type of milk does however make a very thick sour curd.

The composition of soya-bean milk and various products from it has been determined by a number of investigators ; Adolph and (Wu) (3), Remy, (168), Chiu (33), Tso (197)' Fan and Chen (62). The composition of soya-milk as reported in literature has a relatively wide variation as the composition will depend on the method of grinding, variety of beans used, ratio of the water added, the temperature and pH of extraction and the quantities of supplements incorporated.

Zlatarov and Karapetkov (211) have shown that soya-milk resembles animal milk in its physical, chemical and enzymic properties.

VITAMIN B COMPLEX IN SOYA-BEAN MILK :

Kitahara *et al* (104) reported that with the exception of riboflavin, the quantity of B vitamins in soya milk was the same as in cow's milk. Desikachar *et al* (48) found that soya milk is 80 per cent as potent as cow's milk with regard to its content of B group of vitamins. Chang and Murray (24) reported that soya-bean milk and curd contain appreciable quantities of B group vitamins.

VITAMIN C CONTENT OF SOYA-BEAN MILK AND ITS STABILITY :

Sung and Chu (190) reported that soya-bean milk contains negligible amounts of vitamin C. However, the milk prepared from 72 hour germinated beans contains 22.6 mgs./litre as reported by Rangnekar *et al* (163). The percentage of non vitamin C reductants was high during the initial stages of germination. According to these investigators, vitamin C in soya-milk was more stable than cow milk to storage, Cu-catalysed destruction and exposure to sun light. Rangnekar *et al* (164) adopted a modified procedure of vitamin C determination to differentiate non-vitamin C reductants.

NUTRITIVE VALUE OF SOYA-BEAN MILK PROTEIN—EXPERIMENTS ON ANIMALS :

Cheng (30) using the nitrogen balance method with puppies observed that the biological value of soya-bean curd was only 70% as efficient as that of the raw bean. This finding is contrary to that of many workers who have reported that heat treatment of the bean considerably increases the nutritive value of the protein.

Desikachar *et al* (47) studied the nutritive value of soya-bean milk protein at a 10% level by the nitrogen balance method and by the rat growth method. Their results are tabulated below :—

TABLE IV

Nutritive value of soya-bean milk protein

	Biological value	Digestibility co-efficient	Nutritive index	Protein efficiency gain in wt/gm. of protein intake
Cow's milk	82.8	89.7	74.3	1.95
Soya-bean milk	79.2	90.9	72.0	1.80
Raw Soya-bean	55.1	82.8	45.6	...

Desikachar *et al* (54) investigated the utilization of soya-bean milk protein for the formation of blood proteins and found it about 90 per cent as efficient as casein.

TABLE V

Soya-bean milk protein for the formation of blood proteins

	Regeneration of Hæmoglobin			Regeneration of R.B.C.		
	Average Hb. on the 4th day	Average Hb. on the 12th day	% age increase	Average level on 4th day	Average level on 12th day	% age increase
Soya milk protein	8.8	11.7	33.5	3.72	5.47	44.9
Casein	8.4	11.4	36.2	3.63	5.30	45.5

Desikachar *et al* (54) also showed that soya-bean milk protein could maintain normal albumin and globulin level in the blood of rats receiving the milk as their sole source of protein.

TABLE VI

Serum protein fractionations of the blood of rats receiving soya-bean milk protein

(values expressed as mgms. nitrogen per 100 ml.)

	Total nitrogen	Non-protein nitrogen	Protein nitrogen	Albumin nitrogen	Globulin nitrogen	Albumin/Globulin nitrogen
Soya-bean milk protein	937.0	50.6	886.4	622.8	263.6	2.39
Casein	964.0	50.9	913.1	649.9	263.2	2.47

Sahasrabudhe *et al* (177) found that the biological value of soya-milk protein precipitated at pH 4.2 is about 81.5% as determined by regeneration of liver protein in the rat. This is slightly low compared with the results obtained by other methods. The explanation offered by the authors for the low value is the low content of methionine in soya-bean protein which is an important limiting factor in the synthesis of liver protein.

Chang and Murray (24) have recently reported that soya-bean milk was 80% as efficient as milk powder regarding its protein value, whereas the corresponding value for whole bean and curd was 75%. Soya-bean protein supplemented with sesame protein raised the value to 94%.

De and Dutta (37) reported that the biological value of soya-bean milk protein powder prepared from soya-beans, soaked for 24 hours which effects partial germination in the seed, is greater than that of the whole bean. According to them, some changes occur in the amino acid make-up of the protein due to photochemical reaction during germination of the bean. Everson *et al* (61) reported that on germination there was a marked increase in the growth promoting value of soya-bean. Gowri *et al* (77) further reported beneficial effect of germination on the soya-bean milk protein.

Judging from the results of the various animal experiments, it may be concluded that the biological value of the soya-bean protein, as present in the milk, is 80-90% of that of cow's milk. This value could be further improved if the milk is supplemented with small amounts of methionine in which soya-protein is deficient.

There are hundreds of varieties of soya-bean and they vary considerably in the colour of the skin, oil and fibre contents. The same proteins are, however, present irrespective of the variety. Although the investigations in India were largely conducted with only two or three varieties, it may be reasonably assumed that the biological value of the

protein in the milk will be more or less of the same order, irrespective of the variety.

Excepting for citing the factual data, it is difficult to explain, at this stage, the mechanism of improvement in the biological value of the protein as the result of processing into milk. The improved value is noticed even when the *dhal* (deskinned bean which is subjected to incipient germination) is converted into milk. When compared with cooking the whole bean, there is no major difference excepting for certain treatment and the removal of the suspended matter. As the anti-trypsin is destroyed by heat, it cannot be regarded as a major interfering factor, though, in the case of milk, its destruction and elimination may have been more thorough than in the case of the bean cooked to soft centre. The improvement in biological value of the protein is noticed even when the milk is not supplemented with calcium. One fact could possibly explain, at least in part, the observed improvement in biological value. The fraction of soya-bean protein found in soya-bean milk may possess higher nutritive value than that remaining in the residue. This aspect of the subject, therefore, requires more thorough study with particular reference to the mechanism involved.

HUMAN FEEDING EXPERIMENTS WITH SOYA-BEAN MILK PROTEIN :

Chang *et al* (29) studied the nitrogen balance on three subjects and reported that the biological value of the protein in soya-bean curd was 64%. Tso *et al* (200) using the nitrogen balance on two young infants showed that the protein absorption from soya-bean milk approached 90% of the intake. Tso and Chu (199) reported that 80% of the soya-bean milk nitrogen was absorbed whereas the figure for cow milk was 95%. Cahill (23) studied the biological value of the protein of 'Mull soy'—a brand of soya-bean milk processed by Messrs Borden and Co., on nine human subjects and found a value of 95 compared with egg protein as standard.

Desikachar *et al* (49) extended their studies to determine the nutritive value of soya-bean milk protein by human feeding experiment. They found that when cow's milk curd protein fed along with a poor South Indian rice diet is replaced by an equivalent amount of soya-bean proteins, the mixed proteins of the diet in both the cases are utilised to about the same extent. By following the nitrogen balance method on two adult subjects, they (49) reported that the average digestibility co-efficient and the biological value of soya-bean milk protein compared to egg protein are 96.6 and 94.0, respectively. Desikachar and Subrahmanyan (56) conducted feeding experiments on thirty children varying in age from 1 to 3 years, in continuation of their investigations on the comparative absorption and utilisation of proteins from soya-bean milk and cow's milk. They found that soya-bean milk protein was 86% as much utilizable as cow's milk protein.

AVAILABILITY OF CALCIUM AND PHOSPHORUS OF SOYA-BEAN MILK :

Tso *et al* (200) showed that addition of cod liver oil and small quantity of calcium markedly enhanced retention of calcium and phos-

phorus in two young infants. They pointed out that the phosphorus content of soya-bean milk is quite adequate but its utilisation may be affected by the limited intake of calcium.

In a study of calcium utilisation by three Chinese subjects, Adolph and Chen (4) fed 8.1 mg. per kg. body weight of calcium, 80% of which was from cow's milk in control periods and from soya-bean in experimental periods. The calcium from soya-bean milk was well retained and the authors concluded that soya-bean curd and bovine milk are equally effective as source of calcium in the Chinese diet.

Fan *et al* (63) used autoclaved soya-milk and reported that its calcium was as well retained as that in cow's milk, but that the retention of its phosphorus was lower. The utilisation of calcium as studied in adult human subjects by Schroeder *et al* (179) showed that the average per cent utilisation of calcium in evaporated cow's milk was 29.1 and in soya-bean milk 22.6.

Since soya-bean milk contains much less of calcium as compared with cow's milk, Karnani *et al* (99) raised the calcium content of milk to the level of 80 mg. Ca/100 ml. by addition of dicalcium phosphate after adjustment of pH of the milk. The retention of calcium and phosphorus from soya-bean milk compared favourably with cow's milk as the rats retained 82% of calcium and 87% of phosphorus ingested from soya-bean milk. Karnani *et al* (100) further studied the utilisation of calcium from soya-bean milk on young human subjects, 7 to 8 years of age, who received the milks as supplements along with the basal diet. It was found that when 363.5 mg. of calcium from either cow's milk or soya-bean milk was added to the basal diet per day, the average daily calcium balance was changed from (−54.5 mg.) to +24.0 mg. in case of soya-bean milk and to +28.9 mg. in the case of cow's milk. The availability of calcium from the two milks was practically the same as the average utilisation of supplementary calcium from soya-bean milk for affecting positive calcium balance was 23.1% and that from cow's milk was 23.8%.

Desikachar *et al* (49) showed that the calcium of soya-bean milk curd fed to six adult subjects along with a basal low calcium ration was utilised to the extent of about 90% as the calcium of cow's curd. Nandi *et al* (151) reported that vegetable milk prepared from a blend of soya-bean (56 parts), groundnut and ragi malt and containing 0.11% calcium and 0.074% phosphorus, compares favourably with cow's milk for the availability of calcium and phosphorus.

SUPPLEMENTARY VALUE OF SOYA-BEAN MILK TO A POOR SOUTH INDIAN DIET :

Desikachar *et al* (50) studied the supplementary value of soya-bean milk (without addition of extra calcium) to a poor South Indian diet consisting mainly of rice. Soya-bean milk or cow's milk was fed to the rats at a level of 10 ml. per day along with the basal diet. The average weekly increase in weight of the rats was followed over a period of

7 weeks. The results are tabulated below.

TABLE VII

Supplementary value of soya-bean milk to a poor South Indian diet.

Diet fed	Average weekly increase in wt. in gms.
Basal rice diet	2.8
,, ,, ,, + 10 ml. soya-bean milk	5.4
,, ,, ,, + 10 ml. cow's milk	8.2

The results show that a small amount of soya-bean milk given as a supplement practically doubled the growth rate. Basu (214) reported similar results from Dacca. The growth of rats, even when supplemented with soya-bean milk, cannot be regarded as optimal. This is due to the fact that the diet even after supplementing with soya-bean milk is deficient in vitamins and mineral, particularly calcium. Aykroyd and Krishnan (8) found that calcium lactate given as supplement along with rice diet considerably enhanced the nutritive value of the latter and they even suggested that calcium lactate can be used as a milk substitute along with the poor diet.

Karnani *et al* (101) fortified soya-bean milk with calcium and yeast and studied its supplementary value to a poor South Indian diet. The results are presented below :—

TABLE VIII

Supplementary value of fortified soya-bean milk to rice diet.

Diet fed	Average weekly increase in weight in grams.
Basal rice diet ...	3.5
,, ,, ,, + 10 ml. plain soya-bean milk ...	6.6
,, ,, ,, + 10 ml. calcium fortified milk ...	8.1
,, ,, ,, + 10 ml. calcium-yeast fortified soya milk ...	12.4
,, ,, ,, + 10 ml. cow's milk ...	8.6

The above results show that after supplementation with calcium, soya-bean milk has a supplementary value comparable with that of cow's milk. If the milk is further fortified with yeast, its supplementary value becomes even greater than that of cow's milk. The latter observation is of considerable interest and requires to be further confirmed and extended.

DIGESTIBILITY OF SOYA-BEAN MILK :

Van Veen and Schaefer (203) and Smith and Woodraff (182) have described an ingenous procedure adopted by people in Malaya and Indonesia of rendering soya-bean digestible by treating it with a fungus Aspergillus Oryzae.

Glassman and Gologorskaya (69) found that the digestibility of soya-bean milk was about the same as that of cow's milk but the digestibility of soya sour cream was 2-3 times greater than that of the sour cream from cow milk.

Adolph and Wang (6) reported that soya-bean milk has a lower *in vitro* digestibility than that of cow's milk. A similar observation was made by Krishnaswami *et al* (108) who reported that although the *in vivo* digestibility of soya-bean milk is roughly of the same order as that of cow's milk, its *in vitro* digestibility as measured by peptic and tryptic hydrolysis was only about one-fifth of that of the latter. Desikachar, *et al* (57) offered an explanation for this discrepancy by indicating that the poor *in vitro* digestion of soya-milk is due to the presence of the tryptic inhibitor in it. Although, after boiling the milk, the inhibitor retains only 3.5% of its original activity, this amount of the inhibitor interferes with the normal tryptic digestion of the milk protein under *in vitro* conditions.

It is difficult to say whether the above explanation could fully explain the striking disparity between the *in vitro* and *in vivo* observations. In the course of their experiments with infant feeding in orphanages, Desikachar *et al* observed that the infants digested soya-milk at such a fast rate that they required at least three feeds of that milk to two of cow's milk. In feeding experiments with thousands of grown up children in Bangalore, both in the form of milk and curd, no digestive trouble with the soya product was observed. These observations, which are striking, require further explanation. It is possible that the protein passing into the milk may be somewhat different in nature and properties from the one present in the whole soya-bean. This also requires further study.

Apart from the above, Krishnamurti and Subrahmanyan (100) observed that soya-milk does not readily clot with animal rennet. This observation is true of vegetable milks in general. Even if massive quantities of rennet are used, the curd is still soft and spongy. The milks coagulate readily when vegetable rennets are used. The latter clot both animal and vegetable milks with equal facility, whereas animal rennet seems to act effectively only on animal milk. As the human stomach secretes only the animal rennet, the significance of the above observations in relation to the digestion of vegetable milks require to be further studied.

INFANT FEEDING EXPERIMENTS WITH SOYA-BEAN MILK :

This aspect has been exhaustively reviewed by Mackay (116) and Dean (45) who have fully described the ingredients and composition of soya preparations, with details of their practical application in child feeding.

Tso (198) fed infants successfully with soya-bean milk prepared in the ordinary way and found that they grew well and put on weight, just like breast fed infants. Rittinger and Dembo (171) fed fifty infants for a period of one year on soya milk with addition of sugar and various salts and they concluded that soya-bean milk is an adequate food for infants. Rittinger *et al* (172) got encouraging results from the three and half year's study on the growth and development of 205 infants. Guy and Yeh (81) supplemented soya-milk with calcium, vitamin C, cod liver oil and used it successfully for infant feeding. Ni (154) used modified soya-bean milk with marked success for infant feeding in Shanghai refugee camps. Ruhräh (173-175), Schloss (178), Tso *et al* (200), Reid (167) and Fan *et al* (63) also have studied the over all effect of soya-bean milk on infants.

Desikachar *et al* (57) studied the nutritive value of soya-bean milk on infants and toddlers in the Municipal Creches in the Civil Station, Bangalore under the medical supervision of the Lady Health Officer. The results are presented below :

TABLE IX

Increase in weight of toddlers on soya-bean milk.

	No. of Subjects	4 months	8 months	11 months
Cow's milk	40	2.28	2.70	4.00
Soya-bean milk	45	1.58	2.28	3.51

TABLE X

Increase in weight of infants on soya-bean milk

	No. of Subjects	4 months	8 months	11 months
Cow's milk	11	2.60	3.02	2.86
Soya-bean milk	8	2.84	3 72	4.70

The results show that toddlers grew somewhat better on cow's milk, than on soya-bean milk, though the difference was not considerable. The infants, however, responded much better to soya-milk than cow's milk.

Desikachar *et al* (56) further conducted feeding trials with 30 infants in another institution—St. Michael's Convent in Bangalore. The observations showed that all the infants could digest the soya-milk easily and they all put on weight. No digestive disorder was manifested. On the contrary, the Convent authorities reported that when the infants changed over from cow's milk to soya milk, they required more frequent feeding as the soya milk was digested in a shorter time.

Comparative nutritive values of cow and soya milks with respect to the growth of children : Systematic experiments (212, 213) were carried out by the Indian Institute of Science, Bangalore, during 1947 and 1948 under the auspices of the Indian Research Fund Association in collaboration with the Nutrition Research Laboratories, Coonoor and the All-India Institute of Hygiene, Calcutta. The experiments were carried out in four orphanages with about 400 subjects during 1947. The children were dlvided into four groups :—

(*a*) receiving a supplement of 12 ounces of dairy milk per day.

(*b*) receiving a supplement of 12 ounces of soya milk per day.

(*c*) receiving a supplement of 9 ounces of dairy milk per day.

(*d*) Control (No milk).

The experiments were carried out for a period of six months.

The average composition of the dairy milk used for trials during 1947 was as follows :

Fat 3.1%, Protein 3.75% and S.N.F. 8.8%.

The statistical analysis showed that there was no significant difference in regard to the increase in weight among children receiving the different milks as supplements—though all of them were significantly superior to the control group. There was some gradation in the increase in height as observed in the case of the different treatments. (A=0.86"; B=0.75"; C=0.63"; and D=0.57") though they were not statistically significant.

The average hæmoglobin contents in g./100 ml. for the different treatment groups before and after the experiment are shown below:—

TABLE XI.

The average haemoglobin content of children on soya-bean milk

Treatment Group	Before Experiment	After Experiment
A	9.77	10.46
B	9.94	10.46
C	10.49	10.50
D	10.99	10.59

Two of the treatments A and B—cow's milk (12 oz.) and soya milk (12 oz.)—showed appreciable improvement while C (9 oz. of cow's milk) and D (control) showed no improvement. R.B.C. did not show any appreciable change during the period of the experiment. The clinical examinations for various vitamin deficiencies did not reveal any difference during the period of the experiment.

The 1947 season experiments showed that statistically there was no evidence of soya milk being inferior to cow's milk. When examined in terms of age groups, it was observed that the children in the higher age groups did not respond to any of the treatments. It was suggested therefore that for next year's programme, only children from 4 to 9 years of age should be included.

1948 SEASON EXPERIMENTS WITH YOUNG CHILDREN.

In the restricted age group, 186 children were selected and divided into three groups. The following were the three treatments.

A. Cow's milk (12 oz.); B. soya milk (12 oz.) and C. (control with no milk).

With a view to maintaining the solid content of soya-milk at the same level as skimmed milk, the finely divided powder of the incipiently germinated kernel was directly emulsified after the other different usual treatments including the supplementation with calcium. The milk thus prepared had the following composition :—

Total solids 11.2%, protein 5.2%, fat 2.5%, Carbohydrate, 2.9% and Ash 0. 6%.

The dairy milk used in this set of trials had an average fat content of 2% and S.N.F. varying from 8.0—8.5%. The milk was evidently partially skimmed product and it was also diluted to some extent. As no better type of milk was available at that time, the experiments were continued with it as experimental material.

Allowing for the above defect in the quality of milk, it was observed that there was no significant difference in regard to height and weight increase between groups A and B. The control group (C) was inferior to these. These observations were made in regard to all the four Convents in spite of slight variations in regard to the basal diets. Other health observations did not reveal any difference between the different groups.

Arising from the above experiments, it was felt that even further repetitions may not reveal any quantitative difference between the two milks unless the experiments could be conducted with a much larger number of subjects of the right age group for very long periods. As this was not found possible and as the dairy milk available for the trials was not upto the required standard, it was not considered desirable to continue with the studies on the quantitative evaluation of the nutritive values of the two milks. The results were sufficiently conclusive however to show that soya-bean milk had a definite supplementary value to the poor cereal diet and this was recorded by the Nutrition Advisory Committee of the Indian Council of Medical Research at its meeting in 1950. The Committee also recommended that attention may be drawn to the usefulness of soya-bean milk and that the appropriate authorities may be recommended to encourage the cultivation of the bean for the purpose.

FEEDING EXPERIMENTS WITH SOYA-BEAN CURD AT ORPHANAGES AND CONVENTS :

Arising from the scientific studies carried out at the Indian Institute of Science, the then British Resident and other authorities of the Civil & Military Station at Bangalore took keen interest in applying the findings for a programme of mid-day school feeding in a number of institutions (186). It was decided that curd and rice would make a sustaining and wholesome mid-day meal to the children. In order to assess the acceptability of wholesomeness of soya-milk curd, as compared with skimmed milk curd, it was proposed to make two similar preparations, one with each curd. At the same time the cost had to be kept as low as possible so that the expense per child may not exceed Rs. 0-1-3 per day. Sixty-four schools were selected and out of these 6000 children were chosen for the benefit of the mid-day meal. Half the number of children received the rice and soya milk curd preparation. Each child received 12 ounces of the food which was made up with 4 ounces of curd and 8 ounces of cooked rice. The other half, number 3000, received a similar diet in which skimmed milk curd replaced soya milk curd. Both the preparations were made at a central place and sent out to the different schools as just curd and rice without disclosing the identity of the contents. Careful watch was kept over the children at each school and periodical health observations were also made. The feeding programme was continued throughout the school terms for two years. The cost of the food preparations and the distribution, which amounted to a few lakhs of rupees, were met by the Civil Station with the concurrence of the Rationing Adviser to the Government. The cost of the equipment used for the trials and the salaries of a section of the staff were met out of funds provided by the then Department of Food of the Government of India.

The results showed that both the preparations were equally acceptable to the children; that for practical purposes, they could not distinguish one product from the other. All the children maintained good health and the authorities of the station were greatly impressed with the possibility of using soya milk curd exclusively for the mid-day feeding programme. Even after the integration of the Civil Station with the Mysore State, there were a number of proposals for extending the mid-day feeding to a number of centres, but, unfortunately, financial stringency, combined with food shortage, stood in the way.

The mid-day feeding programme did not afford scope for quantitative studies. The numbers involved were very large and the age-groups were also very wide. In order to make observations with restricted age groups, 300 boys, aged 6 12 years, were selected from one of the major institutions. The boys who were all from the low income groups were divided into three groups of 100 each as selected by the random method. The children in the first two groups received per head a mid-day meal consisting of 8 ozs. of separated milk curd of soya-bean milk curd mixed thoroughly with 8 ozs. of cooked rice (equivalent to 2 ozs. of uncooked rice). The remaining group of children served as control without any supplement, and they went to the their respective homes for the mid-day meals.

The soya bean milk used in this experiment (212, 213) for making the curd was prepared by the 'Powder method' with a view to equalise the solid content of the milk with that of cow's milk. It was also fortified

with calcium by the addition of calcium hydrogen phosphate so as to have a level of 90 mgs. of calcium per 100 ml. of the milk. The separated cow's milk (skimmed milk) required for the experiment was supplied by a local dairy.

The heights and weights of the children were recorded on two occasions once at the beginning and the other at the end of the experimental period, which lasted for five months. Besides, a detailed medical evaluation of a selected number of boys in each group was carried out by a medical officer deputed by the Nutrition Research Laboratories, Coonoor. The total number examined comprised 52 subjects in separated cow's curd group, 54 in soya-curd group and 56 children in the control group.

The statistical examination of the results revealed that there was no significant difference with regard to the gain in weight or increase in height between boys receiving soya-curd, or separated cow milk curd; both these groups however were significantly superior to the control group of children who had the lunch in their homes. As for the other health observations, the period of experiment was too short to observe any striking difference between the different groups.

TABLE XII.

Feeding experiments with soya-bean curd (Bangalore School Feeding Scheme).

The experiment included three groups of subjects under the following treatments.

Group A (100 subjects) ... 8 oz. cooked rice+8 oz. separated milk curd.

Group B (100 subjects) ... 8 oz. cooked rice+8 oz. soya-bean curd.

Group C (100 subjects) ... Control (having mid-day meal in their homes)

Distribution of the age of the children in treatment

Age group, years.	Number of Subjects.		
	Group A	Group B	Group C
12	26	25	26
11	33	34	34
10	27	27	27
9	8	8	8
8	5	5	5
Total	99	99	100

Mean growth in weight and height

Age group, (years)	Weight in oz.		
	Group A	Group B	Group C
12	48.36	43.36	30.15
11	40.13	37.07	24.12
10	41.63	38.88	18.37
9 and 8	28.00	25.33	23.53

Age Group, (years)	Height in inches		
	Group A	Group B	Group C
12	0.66	0.70	0.68
11	0.70	0.78	0.54
10	0.73	0.70	0.47
9 and 8	0.67	0.77	0.80

Mean differences in growth between treatments

	Weight			Height		
	Mean diff.	t	5% t	Mean diff.	t	5% t
Xa —— Xb	3.66	0.85	1.96	0.0360	0.73	1.93
Xa —— Xc	15.48	4.26	1.96	0.1413	3.12	1.93
Xb —— Xc	11.82	2.93	1.96	0.1773	3.63	1.93

Therapeutic value of soya-bean milk :

Soya-bean milk is reported to have bean successfully used for treating cases of eczema, Schloss (178), Becker (11). According to Stoesser (185), the iodine number of the serum lipids is lowered in the acute stage of eczema and of other illnesses. When soya-bean milk is used instead of cow's milk in the diet, the iodine number of the serum lipids is quickly restored to normal level because of the high iodine number of soya-bean fat.

Von Noorden (206) reported that milk-from almond, soya-bean, or butter-nut form a much finer curd than cow's milk in the stomach. Such a curd is easily digested. Elimination is also stated to be easy in such a case. Use of soya-milk is recommended in gastric and duodenal ulcer, hypersecretion, disturbances of motility, kidney disease, and uric acid diathesis. The author recommended vegetable milk especially in intestinal stasis and in diabetes. It is useful for diabetics because it contains practically no starch.

Dean (44) successfully treated an advanced case of Kwashiorkor with soya-milk made by spray-drying the liquid filtered from soaked, dehusked, ground and autoclaved beans.

PREPARATIONS FROM SOYA-BEAN MILK :

Tofu (*Teou Fu*) or soya-bean curd is an important oriental soya-bean preparation (35). It is prepared by precipitating the protein from soya-bean milk by calcium or magnesium salts, and pressing the precipitated protein into cakes. In some cases coagulated soya milk is fermented with lactic acid bacteria to remove the beany flavour (92).

Chang and Murray (24) have recently determined the mineral and amino acid contents of soya-bean milk and curd. The curd prepared by precipitating soya milk with a solution of $CaCl_2$ or $CaSO_4$ contained 0.69% calcium on moisture free basis. The curd is thus a very rich source of calcium and plays important role in supplementing Chinese diet. Miller (124) and Miller *et al* (125) have determined the retention of nutrients in commercially processed soya-bean curd. Miller (126) suggested that the dried soya-bean can be fried in deep fat and used in a variety of dishes.

In India, soya-bean curd was prepared by Subrahmanyan and his associates inoculating soya-milk with a mixed culture consisting mainly of *Streptococous lactis* and *para citrovorus*. A little of invert sugar (1-2%) is added to the milk for the propagation of lactic bacteria and consequent development of acid. The beany flavour of milk is almost completely masked as the result of the lactic fermentation. As described earlier the Institution feeding experiments with soya curd showed that the product was very much liked by the subjects and that it supplemented their basal diet.

CHEESE AND OTHER FERMENTED PRODUCTS :

The fresh curd has been called *vegetable cheese*. It is ripened with the characteristic microbes of Swiss cheese (101) or with species of monomucor known as *Mucor Sufu* (36). Horovitz-Vlasova and Livshiaz (90) have described the preparation of kefir and cheese from soya bean milk. Kosturike and Maryash (105) prepared alcoholic and lactic acid fermentation products from soya-bean milk by using *B. lactis acid Leichmann* and a *torula* isolated from Kefir. Milyutina (129) prepared "Soja-Kefir" by the addition of 4% *Dispora caucasica* culture and 1% Bact acidophilus to soya-milk. Kellogg (103) prepared a "butter milk" type of the product by inoculating the sterilised soya-bean milk with *Bacillus* acidophilus.

Li (113, 114) has described the preparation of *Soya Sauce* from soya-bean milk. Soya Sauce represents one of the China's largest uses for

Soya-beans. The Soya Sauce industry is served largely by small plants, which serve their own communities. Brewing Soy Sauce is known to involve the action of moulds, yeasts, and bacteria in that order. Some of the organisms which have been identified as important to the process are *Aspergillus oryzæ, Zygosaccharomyces soja, Z. major* and *Lactobacillus Sp.*

For the detailed information regarding the above products reference may be made to the publications of Smith and Beckel (180) Smith (181), Piper and Morse (162) and Burnett (22).

MICROBIOLOGICAL STUDIES ON SOYA-BEAN MILK :

Kostuirke (105) reported that bacteriological examination of soya-bean revealed the presence of *B. perfringens, B. megatherium* and various strains of *E. Coli* and *B. lactis-acidi Leichmann.* Mild fermentation usually sets in when the beans are soaked in water, the aerobic or the anaerobic organisms being active according to the conditions. The putrefactive spoilage of soya-bean milk is initiated by E. Coli, proteolysed by *B. megatherium* and *B. mesentericus Vulgatus.*

Labarre and Poupart (110) observed that acidogenic and ammoniacal fermentation occurred spontaneously in soya-milk. Boiling the milk prevented the subsequent formation of acidogenic fermentation while ammoniacal fermentation could be prevented by boiling the milk followed by cooling it.

Novotel'nov (155) reported that the milk must be pasteurised at 80°C for 15 minutes to inactivate its oxidase, protease and urease. Winokourov and Palladina (209) found presence of amylose and catalase also in the milk.

Lin (115) has suggested preparation of suitable medium from soya milk which can replace the more expensive meat infusion in routine work and can also be employed for the preservation of stock cultures.

Guhrke and Weiser (79) inoculated cow and soya-bean milks with *L. bulgaricus, L. acidophilus, S. liquefaciens, S. lactis, A. aerogenes* and *E. Coli* and made a comparative study on the rate and extent of peptonisation, acid production, coagulation, pH, reduction of litmus produced by these organisms. The authors conclude that soya-bean milk serves as an excellent culture medium for the propagation of the organisms studied.

DETECTION OF SOYA-BEAN MILK USED AS AN ADULTERANT IN COW'S MILK :

There is a possibility of the adulteration of animal milk with cheap milks of vegetable origin. It is essential that steps are now taken to devise suitable methods for the detection of such adulteration.

Adolph and Yang (5) and Nakayasu (149) have described a method of detecting presence of soya-milk in cow milk. The method is based on the fact that glycinin, the main protein constituent of soya-milk is alkali soluble and is easily oxidisable becoming yellow in colour, while casein and lactalbumin do not become yellow when treated with alkali. Adolph and Yang (5) have also suggested determination of iodine number for detecting adulteration.

RESIDUE LEFT AFTER PREPARATION OF SOYA-BEAN MILK :

During the preparation of milk, about one-third of the bean is not extracted into the emulsion but is left behind as a pasty residue. It also holds a certain proportion of milk which would not be fully recovered in spite of the application of pressure. The composition, properties and uses of this paste have been studied by Subrahmanyan, De and their associates. The residue in the wet state contains about 30% water, 40% protein, 10% carbohydrate, 5·8% oil and the rest representing fibre and other unidentified components. Since it contains a fairly high proportion of water, its keeping quality is very low. It can be used for a variety of sweet and savoury preparations in which a pulse normally forms a component. If fried in oil, it forms good *Vadam* which can be converted into *Dhai Vada* by incorporation of soya-milk curd. If it cannot be used immediately, it should be dried before fermentation sets in. Otherwise it is suitable for use only as animal feed.

Richards (169) dried and toasted the residue and recommended it as a breakfast food. Dobruinina (59) has described the preparation of chocolate from the pressed cake. Dobruinina (59) also suggested that the residue can be sweetened and blended with residues from jam or jelley manufacture to make a good quality pie filling. Oberhard and Kiseleva (157) reported that dry residue from soya-bean milk manufacture is not stable on storage and is sensitive to heat. Its keeping quality is considerably improved if its moisture is kept at 12.9—13% level. They also suggested that the residue can be preserved with 3% aq. lactic acid.

COST OF SOYA-BEAN MILK :

As in the case of other processed products the cost of soya-bean milk will depend, to a large extent, on the price of raw material, the size of output and the extent of mechanisation. Between the years 1945-1950, the price of soya-bean as prevailing in different parts of India varied from Rs. 0-2-3 to Rs. 0-8-0 per lb. exclusive of the cost of packing and transport. The pilot plant trials carried out at Bangalore showed that the yield of milk varied from 4.5 to about 6 lb. per pound of kernel, depending on the variety of bean. With an average daily output of 500 lbs. of milk and with the use of machinery for most of the items of processing, the cost of processing was found to range from Re. 0-1-3 per lb. of milk. If the bean could be obtained in bulk at a cost not exceeding 4 annas per lb., it should be possible to distribute the milk at about 3 annas per lb. If the bean could be produced in the same area and the production is maintained at a higher level, the cost could be further reduced.

When the soya-bean milk is made in the home, the processing and the distribution costs are practically eliminated. The quality of the finished product may not be so good as that made with the machinery. It will also be difficult to add the different minerals and vitamins to fortify the product. The milk, as prepared in the home can, however, be used for a variety of purposes including the preparation of the curd and the butter-milk. The residue can also be used for different food preparations, so that nothing need be wasted.

A great deal of valuable work has already been done to popularise the use of the soya-bean milk in the home. Excellent work has been done by the inmates of the Sevagram at Wardha and other institutions. More extended work in this direction will be very useful.

Groundnut milk and related products.

Attention has already been drawn to the difficulties arising through short supply of soya-bean in India and the desirability of using groundnut, which is more abundant in its place. A great deal of useful work on the processing of groundnut for milk has already been done especially in India and that will be dealt with in the present section.

Dr. Carver (97), who covered practically every aspect of processing groundnut, also showed the possibility of producing the milk; he does not, however, seem to have carried out any detailed investigation to develop a technique for production of milk on a commercial scale. The work of Desikachar *et al* (51) with particular reference to the practical difficulties in the preparation and stability of the milk has already been referred to. Mitchell and Birmingham (130) prepared aqueous emulsions by grinding the nuts in a colloid machine. They recommended the use of Na_2HPO_4 and small quantities of sodium alginate vegetable gums or gelatin to improve the keeping quality of emulsions. Nothing is mentioned about the removal of the nutty flavour from milk or about the nutritive value of the product.

Moorjani and Subrahmanyan (134) conducted systematic studies with the object of overcoming the defects in the product and to produce properly balanced and palatable preparations that will be acceptable to consumers. The improved method of processing as adopted by them consisted in steeping the groundnut kernels in water, removing the outer skin, then grinding to fine paste, adding required quantity of water, filtering to remove the suspended solids, then deodorizing and finally fortification with minerals and vitamins. In a later investigation, Subrahmanyan *et al* (188, 189) showed the possibility of improving the yield of milk from the kernel by 30%. As this improved the efficiency of the process and revealed the commercial possibilities, the details are outlined below :—

Groundnuts are decorticated and the kernels so obtained are mildly roasted at 110-120°C for 5-10 minutes. The roasted groundnuts are cooled, and the testa and the germs are detached by mechanical rubbing. Damaged, shrivelled, rotten and unblanched nuts are discarded. The kernels are then ground into a fine state of division in the dry state using an efficient machine like a mikropulveriser or a kek-mill. The paste is mechanically stirred with water corresponding to about 5 6 times the original weight of the kernels and then filtered through a mull cloth or filter press. The emulsion which thus filters out is treated with saturated lime water to adjust the reaction to pH 6.8 . The emulsion is brought to boil taking care to see that the pH of the milk is maintained at 6.8, extra lime water if necessary being added. Live steam is then bubbled through the milk for about 30 minutes depending upon the quantity of the milk and the quality of the groundnut kernel, to remove the characteristic nutty flavour which is volatile on heating. The steam deodorized milk is then immediately cooled and adequately

fortified with vitamins and buffered with minerals (Ca., Vitamin A, D, B_2 and C). Extra water is added so as to obtain 8 lbs. of milk for every pound of kernels taken. The milk is then passed through an homogenizer or colloid mill to break up the fat globules uniformly and at the same time to disperse uniformly the added salts. According to this method, 1 lb. of kernel yields 8 lbs. of milk containing over 12% solids and there is practically no residue.

Kelkar (102) prepared a good quality groundnut milk from freshly harvested groundnut. Krishna and Lakshminarayana (107) have recently devised a flash deodorizer for removal of the nutty flavour from groundnut milk. Groundnut milk practically free from nutty flavour can also be prepared by emulsifying solvent extracted groundnut cake with refined vegetable oil, using lecithin as an emulsifier (139).

TABLE XIII

Proximate composition of the improved and fortified groundnut milk as compared with cow's milk

Nutrient	Groundnut milk	Cow's milk (216)
	%	
Protein	3.0	3.2
Fat	5.2	4.9
Carbohydrate	3.07	4.6
Ash	0.8	0.74
Total Solids	12.07	13.44
Ca (mgs.)	110	110
P (mgs.)	102	70
Fe (mgs.)	1.47	0.2-0.5 p.p.m.

TABLE XIV

Vitamin content per litre of improved and fortified groundnut milk and cow's milk.

Vitamin	Unit	Groundnut Milk	Cow's Milk
Thiamine	mg.	0.65	0.45
Riboflavin	mg.	2.00	1.70
Nicotinic acid	mg.	11.10	1.26
Ascorbic acid	mg.	17.7	15.9
Vitamin A	I.U.	1400	1320
Vitamin D	I.U.	200	20

Moorjani and Bhatia (137) reported that during the steps involved in the manufacture of groundnut milk, thiamine is lost to the extent of 17% while a lower loss occurs in the case of riboflavin and nicotinic acid.

Desikachar *et al* (55) reported that the overall B. complex content of groundnut milk, as determined by the rat growth method, compares well with that of cow's milk.

FORTIFICATION OF GROUNDNUT MILK WITH CALCIUM AND ITS AVAILABILITY :

Groundnut milk if prepared straight from the kernel is highly deficient in calcium and contains only 9 mg. calcium per 100 ml. as compared with 120 mg. in 100 ml. cow's milk. Moorjani and Subrahmanyan (134) first fortified groundnut milk with calcium to the level of 60 mg. per 100 ml. by first adjusting the reaction to pH 6.6 by addition of lime water followed by incorporation of sodium citrate, di sodium phosphate and calcium gluconate. Metabolic studies with adult rats receiving exclusively cow's milk or calcium fortified groundnut milk showed that in case of cow's milk the precentage retention of the ingested calcium and phosphorus was 34 5 and 39.3, respectively. In the case of groundnut milk the corresponding figures were 31.2 and 34.2 respectively. The retention of calcium and phosphorus from the fortified groundnut milk was thus found to compare fairly well with that of cow's milk. Later, the level of calcium in the milk was raised to 110 mg. in 100 ml. so as to fully correspond to that of cow's milk.

SUPPLEMENTARY VALUE OF GROUNDNUT MILK TO THE RICE DIET :

Desikachar *et al* (51) showed that a milk prepared exclusively out of groundnut has no supplementing value to a poor South Indian rice diet. This is mainly due to the fact that the groundnut milk is very deficient in calcium. Moorjani and Subrahmanyan (135) found that on incorporating calcium to correspond to 60 mg. in 100 ml., the weekly growth rate of rats improved from 3.1 to 7.3 gm. On raising the level of calcium to 110 mg. in 100 ml. the growth rate was further improved though not to the same level as cow's milk.

TABLE XV

Supplementary value of fortified groundnut milk to the rice diet .

Diet	Average weekly growth of rats (in gms.)
Rice Diet	2.3
Rice Diet + 10 ml. calcium fortified groundnut milk	9 7
Rice Diet + 10 ml. cow's milk*	11.9

*Reconstituted from whole milk powder.

NUTRITIVE VALUE OF GROUNDNUT MILK PROTEIN :

Desikachar *et al* (51) showed that the protein in groundnut milk has a relatively lower biological value than that in cow's milk. They prepared

a vegetable milk well balanced in regard to protein by blending groundnut with a small supplement of germinated soya-bean and malted barley (52). The best results with regard to protein quality were obtained by blending germinated groundnut (75 parts) with germinated soyabean (25) parts. The results are presented below :—

TABLE XVI

Effect of incorporation of soya-bean on biological value of groundnut milk protein.

Source of protein	Biological value	Digestibility coefficient.
Raw groundnut	50.0	82.7
Milk from germinated groundnut.	55.4	96.2
Milk from groundnut+soya bean (3:1).	72.9	89.3
Cow's milk	79.2	90.9

The comparative efficiencies of the vegetable milk (prepared from a mixture of groundnut and soya-bean) protein and casein for the regeneration of haemoglobin and red blood cells were studied (136). The results are given below :—

TABLE XVII

Comparative value of vegetable milk protein and casein for Haemopoiesis.

Sources of Protein	Percentage increase over anaemic level	
	Haemoglobin	R.B.C.
Casein	56.66	64.98
Groundnut milk protein.	52.05	54.09

The protein of the vegetable milk was found to be about 91.8 per cent as efficient as casein for haemoglobin regeneration and 71.2% in regard to R.B.C. formation. The protein of the vegetable milk was found to be as good as casein in regard to the maintenance of total serum protein and albumin levels.

TABLE XVIII

Average composition of the serum of rats fed vegetable milk protein and casein.

Protein Source	Total nitrogen per 100 ml. serum	Protein nitrogen per 100 ml.	Albumin nitrogen per 100 ml.	Globulin nitrogen per 100 ml.	Albumin : globulin
	mg.	mg.	mg.	mg.	
Casein	951	903.6	634.0	268.5	2.36
Vegetable milk	963	913.5	637.6	269.9	2.36

The results show that the albumin- globulin ratio in the case of animals receiving both the porteins was the same.

Moorjani and Subrahmanyan (140) studied the supplementary value of vegetable (groundnut + soya) milk protein to wheat flour proteins by the rat growth method, nitrogen balance method and regeneration of liver protein in rat. The results are presented below :—

TABLE XIX

Supplementary value of vegetable milk protein to wheat flour protein

Protein source	Biological value by nitrogen balance method	Gain in weight per g. of protein consumed
Wheat flour	58.0	0.82
Cow's milk	86.0	2.21
Vegetable milk	72.9	1.88
Wheat flour + cow's milk	80.0	2.00
Wheat flour + vegetable milk	67.0	1.79

TABLE XX

Regeneration of liver protein in rats fed vegetable milk protein

(Protein expressed in terms of mgs. of nitrogen per 100 g. body weight.)

Source of protien	Normal level	Fasting level	Regeneration after refeeding for 2 days	Regeneration after refeeding for 4 days.	Liver protein nitrogen increment over fasting level.
Wheat flour	110	80	99	100	20
Wheat flour + vegetable milk	110	80	104	104	24
Wheat flour + cow's milk.	110	80	108	109	29

It was found that with wheat and vegetable milk fed together at 9% protein level, each supplying 50% of the protein, the milk proteins considerably enhanced the nutritive value of wheat flour proteins. This observation is generally in keeping with the well known observation that groundnut cake serves as a useful supplement to wheat.

Nandi and Rajagopalan (150) determined the amino acid make-up of vegetable milk using the circular paper chromatographic technique method. The chromatograph showed that all the bands obtained in the case of cow milk hydrolysate are also present in the vegetable hydrolysate.

GROUNDNUT MILK CURD AND ITS NUTRITIVE VALUE :

Sour groundnut curd is obtained by lactic fermentation in the same way as cow's milk curd. The milk is inoculated with a small amount of preformed milk curd and left overnight when it sets to a thick solid mass. Unlike animal milk groundnut milk does not contain any lactose and hence invert sugar syrup (55° Brix) is added to the milk so as to correspond to 1 per cent level in order to promote the propagation of micro-organisms and consequent development of acidity. Alternatively, the starch of the milk may be hydrolysed by addition of taka-diastase to convert into reducing sugars. As already mentioned it is the fermented product that has found the maximum favour from consumers. The curd and the buttermilk prepared of it are practically indistinguishable from the cow or buffalo milk product in regard to taste and flavour.

Moorjani *et al* (144) succeeded in preserving the vegetable curd by desiccating it. The desiccated curd can be used in a variety of food preparations like 'Avial,' 'Kulan' (or Curry) etc. Moorjani and Bhatia (139) reported that, during the process of curdling, significant increase in the riboflavin content is noticed, with some decrease in the nicotinic acid and no significant change in thiamine content. During the pilot plant trials on the production of groundnut milk curd, it was observed that some stored lots of groundnuts have loosely set curds. Moorjani and Bhatia (138) found that during extended storage, groundnut protein undergoes partial break-down and this may explain the cause of the loose setting since the thickness of the curd is mainly due to coagulation of the protein. Moorjani and Bhatia (141) determined the changes in the nitrogenous constituents of groundnut milk during progressive lactic souring of milk at 37°C over a period of 5 days. The total nitrogen content remained unchanged, while non-protein nitrogen decreased as a result of souring. The titrable acidity of the milk increased on souring for the first two days and later showed a gradual fall.

LARGE SCALE FEEDING TRIALS WITH GROUNDNUT MILK :

During the year 1952-53, some large scale feeding trials extending over some months with vegetable curd or butter milk were conducted as a part of a programme of distress relief. At Hadadi (Mysore State) 600 people were served with one pound of buttermilk each for a period of about 2 months. Later similar work was extended to Ammoor (Madras) with 700 children for a period of 5 months. Though quantitative data could not be obtained, the results showed that the product was generally acceptable and that the subjects maintained normal health.

THE SUPPLEMENTARY VALUE OF GROUNDNUT MILK CURD TO THE DIET OF CHILDREN :

Subrahmanyan *et al* (187) reported supplementary value of groundnut curd to the diet, by following an institutional feeding experiment extending over a period of 6 months with 42 girls aged 4 and 11 years. The results of statistical analysis showed significant increase in the weight, height and nutritional status of children receiving supplement of groundnut curds over those in the control group receiving a similar diet but without the supplement of the curd.

TABLE XXI

Supplementary value of groundnut milk curd to rice diet.

(21 girls in each group)

Character	Increase in control group.	Increase in experimental group.
Height (inches)	0.63	0.96
Weight (lbs.)	1.28	2.56
Haemoglobin (mg./100 ml. blood)	0.17	0.21
Red Blood Cell mil/cu mm.	0.25	0.28

DETECTION OF ADULTERATION OF ANIMAL MILK WITH GROUNDNUT MILK :

Groundnut milk contains a certain percentage of starch and it should therefore be possible to detect its presence either by itself or in blends by the usual iodine test. Even after treatment with Taka-diastase, as followed by the Mysore workers, there will still be some undigested starch which could be detected by the Iodine test.

Pilot plant production and commercial development of groundnut milk: Since 1950, pilot plant trials in regard to the production of fortified groundnut milk have been in progress at the Central Food Technological Research Institute partly with a view to standardising the conditions and partly with a view to demonstrating the value of the product. Although Mysore is a centre where conditions for production of cow and buffalo are favourable and the population is not heavy, the new product has nevertheless found a certain amount of favour, especially from hotels and restaurants which are fairly big consumers. The sale is primarily confined to the sour curd which is the most acceptable product.

Arising out of this experience, several manufacturing firms have come forth with the proposal to produce the milk and the curd. As the shortage of dairy products is more acutely felt on the west coast and

especially in Travancore-Cochin, the first plant was set up at Trichur under the management of a well known South Indian concern. Although the plant started functioning only recently, the product manufactured by it has already been appreciated in the region.

Designs for various types of production units have already been worked out at Mysore. Practically, all the equipment, including the deodorization unit, can be easily obtained or fabricated in India. The following flowsheet for production will be of interest.

Groundnut

(Decortication).

Kernels

Roasting for removal of cuticle.

Cuticle
(for use as animal feed)

Blanched nuts.

(Triple roller mill or mikropulveriser or kek mill)

Fine paste (dry)

(Mixer)

Dilution, mixing and filtration

Residue
(for use in different food preparations or as animal feed.)

Emulsion

Steaming (double jacketed kettle)

Deodorized product.

Mixing tank

Cooling, fortification with minerals and vitamins

Fortified product

(Homogenization)

Sterilized fluid milk.

Inoculation with preformed curd.

CURD.

COST OF GROUNDNUT MILK AND CURD :

In India groundnut is largely a seasonal and speculative crop because, in spite of the large production, methods of storage are inadequate. Inspite of this, groundnut kernel can be obtained over a large part of the country at an average price of 6 annas per lb. The processing cost will depend on the size of output, and the extent of mechanization. The cost per pound of curd of 12.0% solids has been estimated to be about 2 annas.

COST OF GROUNDNUT MILK.

Basis:—Daily Production of 100 lbs. of milk in 8 hrs. (period whole year.)

		Rs.	as.	ps.
1. Raw materials	...	18,741	12	0
2. Production and supervisory labour per shift	...	13,260	0	0
3. Services such as water, electricity, steam, etc.	...	5,490	0	0
4. Fixed charges—depreciation at 10% on equipment and 5% on building	...	4,700	0	0
5. Interest on working capital (20,000) at 5%	...	1,000	0	0
6. Miscellaneous (including transportation, Laboratory expenses)	...	5,000	0	0
	TOTAL	48,191	12	0

Cost of production per pound of milk -/2/1

USE OF GROUNDNUT, MILK CURD AND PRODUCTS PREPARED OUT OF THEM :

Groundnut milk has been used in place of cow or buffalo milk for a variety of food preparations — chiefly sweets. As already mentioned, the milk without further improvement of flavour, cannot replace cow or buffalo milk for coffee or tea, though it goes well with cocoa or ovaltine. The curd, on the other hand, can completely replace the animal milk product for practically every purpose. In India — especially in the South — the buttermilk is the chief dairy product as consumed by the largest section of people. It forms a regular article of diet. The buttermilk prepared out of groundnut milk is thick and creamy and is relished by all consumers. It also makes excellent *Lassi* which can be drunk as a beverage, either in the sweet or salted condition. Other popular preparations out of the curd are *Thair Vada* and *Shrikhand* both of which can be made out of the curd. In Malabar and the South West Coast in general, the people have developed dozens of uses for the milk curd and extensive trials have shown that the groundnut milk curd can be used in exactly the same way.

The keeping quality of the curd is about the same as that of the cow's milk curd. After about 36 hours, both the products start develop- an off-flavour. The curd is best used between 12 and 24 hours after the inoculation of the milk.

As already mentioned, there is practically no residue left after preparation of groundnut milk. Whatever little residue is left over can be used for different food preparations or alternately as animal food. Cow's and buffaloes eat the product with relish.

Other Milk Substitutes

Cashewnut milk : Desikachar *et al* (57) prepared a milk substitute from cashewnut but they experienced the difficulty in stabiiizing it. The milk got curdled on heating. They tried a number of stabilizing agents but none could confer stability on the emulsion. They found that addition of 50 % cow's milk to cashewnut emulsion gave a stable product.

The protein of the milk prepared out of cashewnut kernel has a high digestibility coefficient and biological value. Mitchell *et al* (131) reported that cashewnut protein has a digestibility coefficient of 95 and a biological value of 77.

Moorjani *et al* (143) stabilized cashewnut milk by incorporation of 0.5-1% casein to the emulsion (after adjusting its pH to 7 with lime water) or blending with it 25-50% of groundnut flour or whole groundnut followed by hydrolysis of starch with taka diastase. The milk thus prepared has the following average composition. Total solids 12.55%; protein 3.3%; fat 5.4%; carbohydrate 3.1%; and minerals 0.75%.

At the present time, cashewnut is very expensive, but it may nevertheless be possible to use it in areas where it is abundant. During the processing of cashewnut, 'brokens' are obtained which do not find ready market. These 'brokens' can be processed to yield a milk of good quality in the above manner.

Cocoanut milk : Cocoanut is grown throughout the tropics. It is also widely grown in India and the highest concentration is on the West Coast, especially, in Travancore-Cochin. De *et al* (38) and Vardarajan (204) found that milk from cocoanut has a high percentage of oil without adequate amount of protein to balance it. Moorjani and Bhatia (142) prepared milk from cocoanut at three stages *i.e.* in the tender and mature conditions and as copra. Cocoanut in the tender and mature conditions yielded milk having a very agreeable flavour and taste while the milk from copra (dried cocoanut) had a characteristic flavour of unrefined cocoanut oil. The residue left behind after preparing the milk is quite substantial and this makes the process uneconomical. Stable milk was obtained by blending with it certain quantity of groundnut milk to make up the protein content. Gesteira and Bahia (68) successfully treated more than 50 children suffering from gastro-intestinal disturbances with cocoanut milk.

Gutierrez and Sunico-Suaco (80) have described a method for detecting adulteration of cow's milk with cocoanut milk. The method is based upon Selivanov's test for fructose, a constituent of cocoanut milk. On heating the milk with resorcinol and hydrochloric acid, pink to red colour is obtained.

Almond milk : Stockert and Grunsteidl (184) prepared a vegetable milk by making a 7.5% emulsion of sweet almonds in milk serum. They found that there is no risk of injurious effects through amygdalin from bitter almonds which are likely to be mixed with sweet almonds during the processing for milk.

Ujsàghy (201) found that nitrogen and sulphur of almond milk are retained by healthy infants in the same way as in cow's milk. Chapin and Kast (27) recommended almond milk for feeding children. The results of feeding experiment conductad by them are, however, not very impressive. Chapin (26) recommended that almond milk may be used in nephritis, typhoid fever, intestinal putrefaction, malnutrition, secondary anemia. The milk is rich in vitamins, ferments much less readily than cow milk and contains an easily digestible, emulsified oil. Its proteins are less apt to undergo putrefaction than casein; its high phosphorus and low salt content favour its use in rickets and nephritis ; its low carbohydrate content favours its use in sugar fermentation diseases. Hess (88) succeeded in treating infantile eczema with almond milk supplemented with rice meal, sugar, meat broth, yeast and semolina.

Milk from sun-flower seeds : Dean (45) has described in detail the preparation of a milk from sun-flower seed which was extensively tried for child feeding as a substitute for cow's milk.

Milk from mixed plant sources : Lane (111) prepared a vegetable milk from blend of almonds, unroasted peanuts, whole wheat flour, shorts, soya flour and corn starch. The milk after supplementation with vitamins and minerals was fed to children for a period of 3 years with very encouraging results.

Brickman *et al* (20) prepared a synthetic milk with a fat mixture composed of tallow oil, cocoanut oil, cocoabutter, cod liver oil tallow. The fat mixture corresponded to cow's milk with regard to m.p., saponification, iodine number, and volatile fatty acids. He reported excellent growth response by feeding 311 infants with this synthetic milk for a period of 3 years. Szentirmay (193) has described a process for the manufacture of a substitute of coffee milk mixture. Suzuki *et al* (191, 192) prepared a highly nutritive product called 'Patrogen' which was found to be superior to the other commercial dry milks.

A milk substitute : *Taro* (*Colocasia Esculenta Linn*) Feingold (64) prepared a low cost recipe milk substitute from taro (poyo meal) for use in the diets of milk-sensitive children. The recipe is claimed to be easy to prepare, is palatable and can be given from a bottle.

Borsch milk : Kraus (106) has described preparation of an artificial infant food from soured bran-water suspension (borsch). The milk is prepared from a mixture of bran, corn meal or wheat with or without lactose or sucrose, and the souring induced by the addition of old borsch leaves.

Milk from pulses : Varadarajan (204) attempted to prepare milk from pulses but the product so obtained had the characteristic flavour of the respective grains which could not be masked even by flavouring materials.

Malted milk food : Nicholis (153) states that considerable work was done in the war devastated countries of Italy and Germany to find a milk

substitute for infants and children. Dr. Caporna of the Perani brewery, Rome, invented a product called *Maltavena* prepared from a mixture of a cereal and soya bean. A modified product was prepared in Germany under the name *Lactavena* which proved to be a good milk substitute for infants and children. Chick and Slack (32) found, that a malted food containing malt extract 70%, wheat flour 10%, soya-bean flour 10%, and powdered skimmed milk 10%, was equal in growth promoting value to a mixture of proteins in milk when fed in a diet of equal protein content. Hesse (88) used a modified malt product prepared by blowing hot air through mixture of malt flour and cereal flour. Subrahmanyan *et al* prepared a product similar to 'Maltavena' and showed its possibility for use in India.

The malted products have a great deal to recommend them on the score of palatability and easy digestibility. Even if the vegetable milk is not fully deodorized, the flavour is masked by that of the malt extract. A dried malted milk product thus prepared had the following composition :

Fat 8.78%; protein 16.4%; carbohydrate 67.9%; mineral salts; 3.88%; moiture 3.06%.

The Roberts mechanical cow : The mechanical cow is in operation at Evans Biological Institute at Runcorn, Cheshire under the guidance of Mr. R.S. Roberts, the inventor of this process. From 30 gallons of water, a little sugar and ammonia salts, the mechanical cow makes the equivalent of three gallons of milk a day. A tiny speck of bacterial dust of *Bacillus coli* is washed into a pint of nutrient and placed in an incubator. Then the liquid which has turned cloudy, is made up into ten litres. It is aerated for 24 hours and then made upto 30 gallons. The fluid is churned for five hours, growing thicker and whiter, with a creamy froth on the top. It is then drawn off and pasteurised.

The bacterial product, as prepared above, is claimed to be quite nutritious but though it may look like milk it is not likely to be accepted by the cosumers as a substitute for milk.

Cow tree : Recently, the possibility of using the cow tree as a source of a milk substitute received much attention in India. It is reported that on tapping, the cow tree (*Syn. Brosimum galactodendron D.Dan*) yields a gluey, thickish milk destitute of acridity and exhaling a very agreeable balsamic odour. It is also claimed that the supply of milk from the tree is continuous and that large quantities can be drawn, Chatterjee (28) and Kalipada Biswas (96). Record and Hess (165) have stated that the cow tree latex is apparently harmless to drink if taken in small quantities, but analysis has shown that it has the following composition : 57% water ; 37% wax; and about 5% gum and sugar. Such a product is more suited for making chewing gum than for use as food. Although the people in some South American countries use the product, it cannot be regarded as a substitute for milk.

Summary and Conclusions

Milk is a high class article of food and is required by people at all ages. While every country should produce as much milk as possible. it has been found difficult, in several of the regions, to produce as much milk as

is required for the maintenance of normal health. In such areas, milk substitutes and products prepared out of them would make useful supplements to the dietary of the people. A large amount of work has been done in different parts of the world, and, more recently in India, on processing different oil-bearing seeds to obtain products which could be used in the same way as animal milks. It has been found that when these preparations are suitably buffered and fortified with the same salts and vitamins as present in animal milk, the nutritive values of the preparations are greatly improved and that their supplementary value to the poor cereal dietary makes a fair approach to that of the animal milks. Among such preparations, soya-bean milk is already being used extensively in different parts of the world. In India, soya-bean being in short supply, groundnut has been processed for the preparation of the milk. While the preparation of vegetable milk substitute has not been perfected to the stage of their being fully used in place of cow or buffalo milk for all purposes, the lactic fermented sour curd prepared out of it has been found to be quite acceptable. The use of such a curd would be of special value in regions like the West Coast of India and Assam where milch animals do not normally flourish.

The major obstacles in the way of the extended use of the milk substitutes are (i) unfamiliarity and a certain amount of prejudice and (ii) fear that such products may lead to the adulteration of animal milks and thus interfere with the normal development of the cattle breeding industry and the production of cow and buffalo milks. If, however, there is difficulty in raising the milk production to the required level for the well being of the people, there is a case for the use of the processed substitute products, popularising their uses and, at the same time, taking steps to see that they do not interfere in any way with the maximum production of animal milk in the region. A favourable feature about the production of milk substitutes, especially in India, is the abundance of raw materials and the cheapness of the processed product which would bring it within reach of a large section of people who can ill-afford to buy them at the prevailing high prices.

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—	24.3.70	27-3-70
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—	19.5.70	26.5.70
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